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Effects of Complete Vitamin and Mineral Supplementation in Full Potential All-milk Diets on Growth and Health of Holstein Bull Calves

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Cover Page Footnote

The authors gratefully acknowledge Animix and DSM companies for financial support of the study. We are also very grateful to the Iowa State University Dairy Farm managerial staff, especially Joe Detrick, Mary Healey and Melissa Kosht.

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Summary and Implications

Pre-ruminant Holstein bull calves were fed two diets of pasteurized whole milk (PWM) in amounts that either limited intake or that maximized intake according to common commercial practice. Diets then were either supplemented or not supplemented with a full complement of vitamins and trace minerals (VTM) that met or exceeded NRC requirements. The objective of the study was to quantify the effects of the four feeding strategies on growth of calves, vitamin and mineral statuses in blood, and magnitude of acute phase inflammatory protein expression in response to lipopolysaccharide (LPS) exposure. Calves were assigned randomly to one of four treatment groups (LM-, low milk, not VTM supplemented; LM+, low milk, TMV supplemented; HM-, high milk, not VTM supplemented; HM+, high milk, TMV supplemented) for 15 days. The HM strategy increased average daily gain in calves, but VTM supplementation did not improve growth during the first two weeks of life. Calves fed more milk had greater magnesium and copper concentrations in blood plasma, but treatment groups did not differ in acute phase protein expression.

Introduction

Calves on dairy farms throughout the United States are fed pasteurized whole milk (PWM) to recover productive losses from mastitis. Proponents of PWM diets claim that bovine milk is an optimal diet for bovine offspring, but conventional feeding approaches often limit milk intake to encourage dry starter-grain intake. Grain is normally fortified with vitamins and trace minerals (VTM), and PWM is not commonly VTM fortified. Both caloric and VTM malnutrition may occur early in life before grain intake is optimized. To avoid malnutrition in calves, "full potential" dietary programs have been implemented that maximize dry matter intake from milk or milk replacer, but contributions of full-potential PWM diets to vitamin and mineral requirements of the calf remain largely unexplored, as do the effects of caloric and VTM malnourishment on intestinal immune functions in the humorally naïve neonate. Given that the first several weeks of the calf's life represent

the period of microbial colonization of the rumen and intestine, that VTM have been implicated in numerous innate barrier and response functions, and that calves express highest overall morbidity rates at 10-14 days of age, the effects of the above feeding strategies on potential malnourishment and subsequent effects on induction of inflammation warrant further investigation.

Materials and Methods

Experimental Design

Neonatal bull calves (n=24) were collected at birth and assigned randomly to one of four dietary treatments in a 2-by-2 factorial completely randomized design. Calves were fed 1.9 L (LM) or 3.8 L (HM), respectively, of pasteurized whole milk twice daily for 15 days. Milk was either supplemented (LM-, HM-) or not supplemented (LM+, HM+) with vitamins and trace minerals (VTM) that met or exceeded NRC requirements. Calves were not offered additional hay or grain, and water was offered ad libitum.

All calves were challenged on d 14 of age with LPS (*Escherichia coli* 0111:B4; L2630; Sigma, St. Louis, MO). Calves were injected subcutaneously immediately posterior to the scapula with 3 µg/kg of BW of LPS at 0700 h. to stimulate inflammation.

Sample Collection and Analysis

Peripheral blood was collected from calves at days 0, 13, and 15 for quantification of VTM, immunoglobulin G1 (IgG1), and acute phase proteins haptoglobin and serum amyloid A.

Calves were weighed at birth and again at day 15. Plasma and serum were used for quantification of minerals. Haptoglobin was quantified in serum by using a bovine-specific ELISA (Immunology Consultants Laboratory, Inc., Newberg, OR). Serum amyloid A was quantified by using a multispecies serum amyloid A ELISA (Tridelta Development Ltd. Maynooth, Co. Kildare, Ireland). IgG1 was quantified by using capture ELISA.

Statistical Analysis

Data were analyzed by repeated measures ANOVA by using mixed procedures of SAS (Statistical Analysis Software, Version 9.3, SAS Institute, Inc., Cary, NC). Calf served as the experimental unit for all analyses and as the random effect in the statistical model. The model included main effects of milk, VTM, day, and all possible interactions of main effects. Least squares means were compared via the *pdiff* statement in SAS, and *P*-values were adjusted by the Tukey-Kramer method. Means were

considered different when $P < 0.05$. Results are reported as least squares means \pm SEM.

Results and Discussion

Body weight gain of calves during the 15-d period is shown by treatment group (Table 1). HM calves exhibited significantly greater average daily gain than did LM calves. VTM supplementation did not improve average daily gain.

Dietary treatment did not affect the concentration of circulating IgG1 or expression of serum amyloid A or haptoglobin in calves (Table 2).

Calves fed the HM diet exhibited significantly greater concentrations of copper and magnesium in blood and exhibited a trend for greater concentration of phosphorus ($p = 0.079$). VTM supplementation did not affect mineral concentrations in blood of calves. Calves had greater calcium, iron, and magnesium at d 1 than at d 13 and 15, but

copper, phosphorus, and zinc concentrations in blood of calves increased with age. (Table 3). This accumulation indicates that these minerals were supplied in excess.

Collectively, HM diets increased average daily gain of calves during early life, but VTM supplementation did not affect growth performance, VTM concentration, or expression of inflammatory acute phase proteins during LPS challenge. The results suggest that fetal deposits of minerals and vitamins after birth may be sufficient to sustain the calf at least for a short period.

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Table 1. Effect of milk fed strategy and VTM supplementation on average daily gain and body weight of young calves

	Treatments				SEM	P-value	
	LM-	LM+	HM-	HM+		Milk	VTM
Birth weight, kg	45.76	44.96	47.27	42.23	1.859	0.75	0.14
Final weight at day 15, kg	51.97	50.40	54.55	49.62	2.013	0.67	0.13
Average daily gain, kg/d	0.41 ^{ab}	0.36 ^b	0.48 ^{ab}	0.49 ^a	0.044	0.03	0.64

LSM in same row with different superscripts means that are different ($p < 0.05$)

Table 2. Effect of milk fed strategy and VTM supplementation on immunoglobulin, and inflammatory acute phase proteins of young calves

	Treatments				SEM	P-value		
	LM-	LM+	HM-	HM+		Milk	VTM	Day
IgG, mg/mL	3.05	5.49	4.04	2.26	1.599	0.49	0.84	0.74
Haptoglobin, μ g/mL	210.8	245.4	724.7	228.4	187.91	0.20	0.24	0.31
Serum amyloid A, μ g/mL	277.7	326.6	370.3	209.3	79.61	0.88	0.49	0.32

Table 3. Effect of milk fed strategy and VTM supplementation on plasma mineral concentration of young calves (mg/L)

	Treatments				SEM	P-value		
	LM-	LM+	HM-	HM+		Milk	VTM	Day
Ca (mg/L)	104.8	107.1	107.8	106.5	2.57	0.66	0.85	0.007
Cu (mg/L)	0.73 ^{ab}	0.72 ^b	0.85 ^{ab}	0.87 ^a	0.041	0.001	0.99	0.0001
Fe (mg/L)	1.06	1.12	1.12	1.27	0.166	0.54	0.53	0.005
Mg (mg/L)	18.09	17.88	19.02	19.01	0.539	0.046	0.71	0.03
P (mg/L)	78.06	73.87	84.43	81.90	3.599	0.079	0.44	0.0001
Zn (mg/L)	0.92	0.92	0.98	1.07	0.067	0.14	0.52	0.007

LSM in same row with different superscripts means that are different ($p < 0.05$)